

National Institute
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National Voluntary
Laboratory Accreditation Program

ISO/IEC 17025:1999
ISO 9002:1994

Scope of Accreditation



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CALIBRATION LABORATORIES

NVLAP LAB CODE 105002-0

SANDIA NATIONAL LABORATORIES

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NVLAP Code: 20/A01

ANSI/NCSL Z540-1-1994; Part 1

Compliant

DIMENSIONAL

NVLAP Code: 20/D01

Angular

Range	Best Uncertainty (\pm) ^{note 1}	Remarks
Angle Blocks	0.60 arc second	Standard Sizes, 1 arc second to 45°
Optical Squares	0.46 arc second	
True Squares	0.28 arc second	

December 31, 2004

A handwritten signature in black ink, appearing to read "Wm R. Mahr".

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NVLAP Code: 20/D01

Angular/Rotary Index Tables and Optical Polygons

<i>Range</i>	<i>Best Uncertainty (\pm)^{notes 1,2}</i>	<i>Remarks</i>
30° increments	0.08 arc second	Stack Method
30° increments	0.50 arc second	Comparison Method

NVLAP Code: 20/D03

Gage Blocks

<i>Range</i>	<i>Best Uncertainty (\pm)^{notes 1,7}</i>	<i>Remarks</i>
to 100 mm to 4 in	(35 + 0.53 L) nm, L in mm (1.38 + 0.53 L) μ in, L in inches	Interferometry, single wring
< 1 mm	42 nm	Mechanical Comparison to
< 0.04 in	1.65 μ in	Masters ^{notes 2,3,4}
1 to 100 mm .04 to 4 in	(37 + 0.62 L) nm, L in mm (1.46 + 0.62 L) μ in, L in inches	Mechanical Comparison to Masters ^{notes 2,3,4}
125 to 500 mm 5 to 20 in	(127 + 0.30 L) nm, L in mm (5.0 + 0.30 L) μ in, L in inches	Mechanical Comparison to Masters ^{notes 2,3,4}

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NVLAP Code: 20/D07

Thread Measuring Wires

Range	Best Uncertainty (\pm) ^{notes 1,2}	Remarks
All Standard 29° and 60°	165 nm (6.5 μ in)	Comparison to NIST-calibrated masters

NVLAP Code: 20/D08

Optical Reference Planes

Range	Best Uncertainty (\pm) ^{notes 1,2}	Remarks
to 10 inch diameter	1.2 μ in (30nm)	Comparison to NIST-calibrated masters

NVLAP Code: 20/D09

Roundness

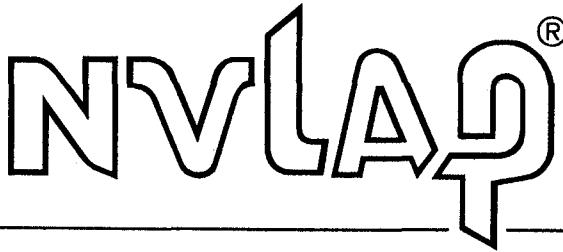
Range	Best Uncertainty (\pm) ^{notes 1,2}	Remarks
to 100 mm	5.4 nm + 5.1% of value	Spindle error deconvolution at limited points.
to 4 in diameter	0.2 μ in + 5.1% of value	Spindle error deconvolution at limited points.
to 350 mm	10.6 nm + 6.8% of value	Spindle-compensated trace. Uncertainty will increase for large artifacts
to 14 in diameter	0.42 μ in + 6.8% of value	Spindle-compensated trace. Uncertainty will increase for large artifacts.

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NVLAP Code: 20/D11

Spherical Diameter; Plug/Ring Gages

Range	Best Uncertainty (\pm) ^{notes 1,2}	Remarks
1 to 25 mm	150 nm	Gaging Balls Calibration Spheres; Comparison to NIST-calibrated masters
0.03125 to 1 in	5.91 μ in	Gaging Balls Calibration Spheres; Comparison to NIST-calibrated masters
to 250 mm	(230 + 1.7 L) nm, L in mm	Plain plug/ring gages
to 10 in. 0.03125 to 1 in	(9.0 + 1.7 L) μ in, L in inches	Plain plug/ring gages

NVLAP Code: 20/D12

Surface Texture

Range	Best Uncertainty (\pm) ^{notes 1,2}	Remarks
0.0125 to 3.0 μ m	2.5%	Step Height Standards
0.5 to 120 μ in		
0.0125 to 3.0 μ m	7.0 nm + 1.5%	Ra (Roughness Average)
0.5 to 120 μ in	0.28 μ in + 1/5%	

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DC/LOW FREQUENCY

NVLAP Code: 20/E01
Current/ AC-DC Difference

*Best Uncertainty (\pm) in ppm^{note 1}
Frequency in Hz*

<i>Range</i>	<i>100</i>	<i>50 k</i>	<i>100 k</i>
10 mA	53	72	15
25 mA	51	73	19
50 mA	51	75	21
100 mA	51	108	26
250 mA	53	73	67
0.5 A	51	73	32
1.0 A	51	79	43
2.5 A	53	87	60
5.0 A	104	197	63
10.0 A	101	154	91
20.0 A	107	160	89

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NVLAP Code: 20/E03

Capacitance Dividers - Pulsed High-Voltage Condition

Range	Best Uncertainty (\pm) in percent ^{note 1}	Remarks
1 to 350 kV	2.0	1 to 30 μ s Pulse

NVLAP Code: 20/E05

DC Resistance

Range in ohms	Best Uncertainty (\pm) in ppm ^{note 1}	Remarks
0.0001 to 0.001	5	6010 + 6011 System Time of Test
0.001 to 0.01	0.35	6010 + 6011 System Time of Test
0.01 to 0.1	0.29	6010 + 6011 System Time of Test
0.1 to 1	0.21	6010 + 6011 System Time of Test
1	0.055	6010 + 4220 + double substitution Time of Test
1 to 10	0.076	6010 + 4220 System Time of Test

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10 to 100	0.09	6010 + 4220 System Time of Test
100 to 1000	0.11	6010 + 4220 System Time of Test
1000 to 10 k	0.15	6010 + 4220 System Time of Test
10^4 to 10^5	0.20	6000 + 4220A System Time of Test
10^5 to 10^6	0.25	6000 + 4220A System Time of Test
10^6 to 10^7	0.29	6000 + 4220A System Time of Test
10^7 to 10^8	0.58	6010 + 4220 System Time of Test
10^8 to 10^9	5.0	6000 + 4220A System Time of Test
10^9 to 10^{10}	470	Terraohm Meter
10^{10} to 10^{11}	670	Terraohm Meter
10^{11} to 10^{12}	1400	Terraohm Meter

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10^{12} to 10^{13}	2000	Terraohm Meter
10^{13} to 10^{14}	3300	Terraohm Meter
10^{14} to 10^{15}	6700	Terraohm Meter
10^{15} to 10^{16}	7.0%	Terraohm Meter
Shunts		
100 mA to 2500 A	2.5	

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NVLAP Code: 20/E06

DC Voltage

Range	Best Uncertainty (\pm) in ppm ^{note 1}	Remarks
1.0 to 1.018 V	0.14	Josephson Array Systems Zeners and DVMs
10.0 V	0.017	Josephson Array Systems Zeners and DVMs

Pressure coefficient of Voltage for Solid State Voltage Standards

Pressure Coefficient of Voltage	Best Uncertainty (\pm) in ppm ^{note 1}	Remarks
>5 nV/hPa	2 nV/hPa	-2000 to +3000 m elevation (Difference Measurement)
0 to 5 nV/hPa	0.1 nV/hPa	-2000 to +3000 elevation (Josephson Array Measurement)

Voltage divider - Potentiometer combination

1.5 V to 1500 V	2.5	Volt Box-Potentiometer, k=2
x1.0 range to 1.05 V	0.5 of reading + 0.1 μ V	Potentiometer only, k=3
x1.0 range above 1.05 V	1.0 of reading + 0.1 μ V	Potentiometer only, k=3
x0.1 range	1.5 of reading + 0.01 μ V	Potentiometer only, k=3
x0.01 range	2.5 of reading + 0.005 μ V	Potentiometer only, k=3

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Automated Intermediate Voltage System

0 to 10.0 V	0.5 + 0.2 μ V	Automated Potentiometer System
10 to 30 V	1.4	Automated Potentiometer System
300 to 1200 V	4.0	Automated Potentiometer System

High Voltage - Electrostatic Voltmeters, etc.

to 100 kV	106	200 kV system
100 kV to 200 kV	140	200 kV system
to 10 kV	0.2%	10 kV system

Ratio/Bridges

1:1 to 1:100,000	0.5×10^7 (ratio)	For ratio based on 20 step first dial ($k=3$). For bridges, uncertainty combines ratio and resistance uncertainties
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NVLAP Code: 20/E08

Inductive Dividers

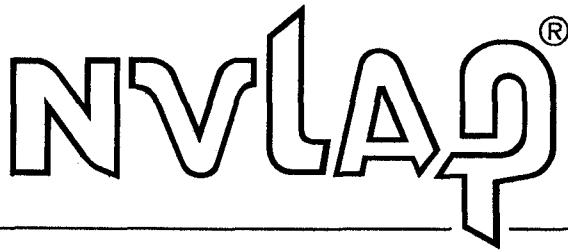
Range	Best Uncertainty (\pm) in ppm ^{note 1}	Remarks
15, 35 and 100 V	55	@ 60,1 k and 10 kHz

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NVLAP Code: 20/E09
Voltage/ AC-DC Difference

Best Uncertainty (\pm) in ppm^{note 1}
Frequency in Hertz

<i>Range in Volts</i>	<i>10</i>	<i>20</i>	<i>50</i>	<i>100</i>	<i>200</i>	<i>500</i>	<i>1 k</i>	<i>2 k</i>	<i>5 k</i>	<i>10 k</i>	<i>20 k</i>	<i>50 k</i>
1	21	12	11	8	7	5	6	5	6	5	7	8
2	16	16	10	8	6	5	8	7	15	13	6	7
3	16	14	11	6	6	6	10	10	10	9	9	9
4	18	13	11	7	6	6	8	6	6	7	8	7
6	23	15	14	13	15	14	13	10	10	9	8	8
10	17	13	11	8	10	7	11	11	13	13	12	13
12	19	13	11	8	10	11	10	11	10	10	11	9
20	31	14	11	6	6	7	7	8	7	8	9	9
30	19	15	11	8	6	8	8	9	8	8	9	12
40	30	14	11	17	6	8	18	9	8	8	16	21

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60	20	14	13	7	7	9	8	8	8	8	9	12
100	35	14	12	7	7	8	9	8	8	8	10	13
120	102	23	21	22	21	9	10	9	9	9	11	15
200	101	21	21	22	21	10	12	12	13	11	15	23
300	101	21	21	21	21	12	14	14	11	11	14	24
400	101	21	21	23	21	13	14	15	15	15	18	28
600	102	22	21	21	21	16	16	15	16	15	21	32
1200	102	21	22	22	21	17	18	17	22	19	22	26

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NVLAP Code: 20/E09

LF AC Voltage

*Best Uncertainty (\pm) in ppm^{note 1}
Frequency in Hertz*

<i>Range in Volts</i>	<i>100 k</i>	<i>200 k</i>	<i>500 k</i>	<i>1 M</i>
1	4	75	82	86
2	10	74	74	76
3	11	72	77	81
4	10	71	71	71
6	9	73	75	81
10	11	72	71	74
12	13	72	73	72
20	11	71	72	71
30	14	72	77	78
40	21	91	106	71

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60	14	72	74	73
100	23	90	91	134
120	19			
200	35			
300	45			
400	51			
600	59			
1200	49			

NVLAP Code: 20/E10
LF Capacitance

Range	Best Uncertainty (\pm) in ppm ^{note 1}	Remarks
0.01 to 1000 pF	5	@ 1 kHz

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NVLAP Code: 20/E11

LF Inductance

Best Uncertainty (\pm) in percent^{note 1}
Frequency in Hz

<i>Range</i>	<i>100</i>	<i>1 k</i>	<i>10 k</i>
10 μ H	1.10	0.20	0.20
20 μ H	0.50	0.20	0.20
50 μ H	0.20	0.20	0.20
100 μ H	0.10	0.10	0.10
200 μ H	0.10	0.10	0.10
500 μ H	0.02	0.02	0.05
1 mH	0.02	0.02	0.06
2 mH	0.03	0.03	0.06
5 mH	0.03	0.03	0.06
10 mH	0.02	0.02	0.05
20 mH	0.02	0.02	0.05
50 mH	0.02	0.02	0.05
100 mH	0.02	0.02	0.05

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200 mH	0.02	0.02
500 mH	0.02	0.02
1 H	0.02	0.05
2 H	0.02	0.05
5 H	0.02	0.10
10 H	0.02	0.20

NVLAP Code: 20/E18

Resistive Dividers - Pulsed High-Voltage Condition

Range	Best Uncertainty (\pm) in percent ^{note 1}	Remarks
1 to 350 kV	1.0	1 to 30 μ s Pulse

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TIME AND FREQUENCY

NVLAP Code: 20/F01
Frequency Dissemination

Range	Best Uncertainty (\pm) ^{note 1}	Remarks
0.1 MHz	1 part in 10^{12}	
1 MHz	1 part in 10^{12}	
5 MHz	1 part in 10^{12}	
10 MHz	1 part in 10^{12}	

IONIZING RADIATION

NVLAP Code: 20/I04
Radioactive Sources

Range	Best Uncertainty (\pm) ^{note 1}	Remarks
Alpha Emission Rate		
1 to 2×10^5 /s into 2π	2.0 %	
Beta Emission Rate		
50 to 5000 /s into 2π	3.0 %	

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Alpha Energy

MECHANICAL

NVLAP Code: 20/M06

Force

Range in lb	Best Uncertainty (\pm) in percent^{notes 1,2,5}	Remarks
100 to 1,000	0.0052	Primary Standard (Deadweight)
1,000 to 100,000	0.016	Secondary Standards (Proving Rings)
50 to 30,000	0.075	Secondary Standards (Load Cells) ^{note 6}

NVLAP Code: 20/M08

Mass

<i>Range</i>	<i>Best Uncertainty (±)^{notes 1,2}</i>	<i>Remarks</i>
60 kg	46.4 mg	Multiple double substitution or equivalent
50 kg	41.8 mg	Multiple double substitution or equivalent
30 kg	34.1 mg	Multiple double substitution or equivalent
25 kg	10.5 mg	Multiple double substitution or equivalent
20 kg	7.3 mg	Multiple double substitution or equivalent

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10 kg	1.10 mg	Multiple double substitution or equivalent
5 kg	0.55 mg	Multiple double substitution or equivalent
3 kg	0.32 mg	Multiple double substitution or equivalent
2 kg	0.22 mg	Multiple double substitution or equivalent
1 kg	0.091 mg	Redundant weighing design
500 g	0.048 mg	Redundant weighing design
300 g	0.032 mg	Redundant weighing design
200 g	0.024 mg	Redundant weighing design
100 g	0.022 mg	Redundant weighing design
50 g	0.0132 mg	Redundant weighing design
30 g	0.0095 mg	Redundant weighing design
20 g	0.0083 mg	Redundant weighing design
10 g	0.0087 mg	Redundant weighing design
5 g	0.0049 mg	Redundant weighing design
3 g	0.0036 mg	Redundant weighing design
2 g	0.0029 mg	Redundant weighing design
1 g	0.0031 mg	Redundant weighing design

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500 mg	0.0021 mg	Redundant weighing design
300 mg	0.0016 mg	Redundant weighing design
200 mg	0.0015 mg	Redundant weighing design
100 mg	0.0017 mg	Redundant weighing design
50 mg	0.00102 mg	Redundant weighing design
30 mg	0.00076 mg	Redundant weighing design
20 mg	0.00068 mg	Redundant weighing design
10 mg	0.00074 mg	Redundant weighing design
5 mg	0.00056 mg	Redundant weighing design
3 mg	0.00048 mg	Redundant weighing design
2 mg	0.00045 mg	Redundant weighing design
1 mg	0.00053 mg	Redundant weighing design

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Mass Avoirdupois

Range	Best Uncertainty ^{notes 1,2}	Remarks
100 lb	142.6 μ lb	Multiple double substitution or equivalent
50 lb	68.0 μ lb	Multiple double substitution or equivalent
25 lb	36.2 μ lb	Multiple double substitution or equivalent
20 lb	25.1 μ lb	Multiple double substitution or equivalent
10 lb	12.5 μ lb	Multiple double substitution or equivalent
8 lb	9.9 μ lb	Multiple double substitution or equivalent
5 lb	6.6 μ lb	Multiple double substitution or equivalent
4 lb	4.8 μ lb	Multiple double substitution or equivalent
3 lb	3.6 μ lb	Multiple double substitution or equivalent
2 lb	2.4 μ lb	Multiple double substitution or equivalent
1 lb	1.21 μ lb	Multiple double substitution or equivalent
500 mlb	0.62 μ lb	Multiple double substitution or equivalent
300 mlb	0.38 μ lb	Multiple double substitution or equivalent
200 mlb	0.26 μ lb	Multiple double substitution or equivalent
100 mlb	0.13 μ lb	Multiple double substitution or equivalent

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50 mlb	0.074 μ lb	Multiple double substitution or equivalent
30 mlb	0.046 μ lb	Multiple double substitution or equivalent
20 mlb	0.032 μ lb	Multiple double substitution or equivalent
10 mlb	0.020 μ lb	Multiple double substitution or equivalent
5 mlb	0.016 μ lb	Multiple double substitution or equivalent
3 mlb	0.014 μ lb	Multiple double substitution or equivalent
2 mlb	0.0109 μ lb	Multiple double substitution or equivalent
1 mlb	0.0107 μ lb	Multiple double substitution or equivalent
0.5 mlb	0.0095 μ lb	Multiple double substitution or equivalent
0.3 mlb	0.0106 μ lb	Multiple double substitution or equivalent
0.2 mlb	0.0095 μ lb	Multiple double substitution or equivalent
0.1 mlb	0.0083 μ lb	Multiple double substitution or equivalent
10 oz	12.2 μ oz	Multiple double substitution or equivalent
8 oz	9.9 μ oz	Multiple double substitution or equivalent
5 oz	6.4 μ oz	Multiple double substitution or equivalent
4 oz	5.2 μ oz	Multiple double substitution or equivalent

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3 oz	3.9 μ oz	Multiple double substitution or equivalent
2 oz	2.7 μ oz	Multiple double substitution or equivalent
1 oz	1.4 μ oz	Multiple double substitution or equivalent
1/2 oz	0.76 μ oz	Multiple double substitution or equivalent
1/4 oz	0.44 μ oz	Multiple double substitution or equivalent
1/8 oz	0.29 μ oz	Multiple double substitution or equivalent
1/16 oz	0.21 μ oz	Multiple double substitution or equivalent
1/32 oz	0.19 μ oz	Multiple double substitution or equivalent

RF MICROWAVE

NVLAP Code: 20/R05
HF Capacitance

Best Uncertainty (\pm) in percent^{note 1}
Frequency in Hz

<i>Range in pF</i>	<i>100</i>	<i>1 k</i>	<i>10 k</i>	<i>100 k</i>	<i>1 M</i>
0.01		0.20		1.3	
0.1		0.05		1.3	
1		0.02		0.04	

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10	0.01	0.02	
100	0.01	0.01	
1000	0.01	0.03	
1	0.02	0.2	0.30
2	0.02	0.35	0.60
5	0.02	0.22	0.26
10	0.10	0.14	0.15
20	0.10	0.13	0.11
50		0.03	0.02
100		0.02	0.02
200		0.01	0.01
500		0.02	0.01
1000		0.02	0.03
10	0.0001		

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100		0.0001			
1	0.01	0.01	0.01	0.01	0.01
10	0.01	0.01	0.01	0.01	0.01
100	0.01	0.01	0.01	0.01	0.01
1000	0.01	0.01	0.01	0.01	0.01

NVLAP Code: 20/R06

HF Inductance

Best Uncertainty (\pm) in percent^{note 1}
Frequency in Hz

<i>Range</i>	<i>10 k</i>	<i>100 k</i>	<i>1 M</i>	<i>10 M</i>
0.1 μ H		2.19	4.00	
0.2 μ H		2.03	2.03	
0.5 μ H		0.80	1.20	
1.0 μ H		0.56	0.92	
2.0 μ H		0.31	0.73	
5.0 μ H		0.25	0.68	

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10 μ H	0.39	0.63		
25 μ H	0.32	0.16		
50 μ H	0.26	0.12		
100 μ H	0.24	0.11		
250 μ H	0.32	0.16		
500 μ H	0.26	0.09		
1 mH	0.24			
2.5 mH	0.25			
5 mH	0.24			
10 mH	0.29			
25 mH	0.25			
0.25 μ H	1.2	1.4	1.7	0.8
1 μ H	0.4	0.5	0.9	0.6
10 μ H	0.4	0.4	0.6	0.1
100 μ H	0.2	0.2	0.2	

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Q Standards

Range	Best Uncertainty (\pm) in percent ^{note 1}	Remarks
Selected values from 95 to 607	1.2 to 4.5 dependent on Q value and frequency	frequency range 50 kHz to 45 MHz

NVLAP Code: 20/R11
RF-DC Voltage Converter

High Frequency TVC

Best Uncertainty (\pm) in percent^{note 1}
Frequency in Hz

Range	1 M	10 M	30 M	50 M	100 M
0.5 V	0.042	0.042	0.16	0.40	0.86
1 V	0.041	0.086	0.16	0.40	0.86
2 V	0.06	0.11	0.21	0.51	1.1
2.5 V	0.06	0.10	0.20	0.51	1.0
3 V	0.06	0.11	0.21	0.51	1.1
5 V	0.06	0.11	0.20	0.50	1.0
10 V	0.06	0.10	0.20	0.50	1.0
20 V	0.06	0.10	0.20	0.50	1.0

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50 V	0.06	0.10	0.20	-	1.0
100 V	0.06	0.10	0.21	-	1.4
200 V	0.07	0.10	0.22	-	1.5

RF TVC

*Best Uncertainty (\pm) in percent^{note 1}
Frequency in Hz*

Range	300 M	600 M	700 M	800 M	900 M	1000 M
1 V	1.3	1.3	1.3	1.3	1.3	1.3
2.4 V	1.3	1.3	1.3	1.3	1.3	1.3
7 V	1.3	1.3	1.3	1.3	1.3	1.3

Micropotentiometers

*Best Uncertainty (\pm) in percent^{note 1}
Frequency in Hz*

Range	30 M	100 M	300 M	600 M	900 M
0.1 mV	2.32	3.56	3.36	5.10	5.10
0.2 mV	0.54	1.04	1.02	1.35	1.42

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0.4 mV	2.34	3.44	3.18	5.10	5.10
0.9 mV	0.54	1.04	1.05	1.35	1.44
1 mV	2.24	3.33	3.21	5.10	5.10
1.5 mV	0.59	1.02	1.02	1.33	1.33
4 mV	0.53	1.07	1.21	1.38	1.39
5 mV	2.24	3.16	3.17	5.10	5.10
10 mV	2.27	3.19	3.16	5.10	5.10
11 mV	2.25	3.17	3.58	5.10	5.10
25 mV	0.48	0.97	0.97	1.28	1.30
28.5 mV	2.52	3.49	3.95	5.10	
102 mV	0.53	0.99	1.08	1.30	1.28
150 mV	0.43	0.99	1.06	1.32	1.28
320 mV	2.24	3.23	3.18	5.10	5.10
330 mV	0.45	1.01	0.98	1.38	1.29

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NVLAP Code: 20/R12
RF/Microwave Bolometer Units

Expanded Uncertainties^{notes 1,2,3} on Effective Efficiency & Calibration Factor of HP bolometric power sensors.

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			10-2000	2000-8000	8000-12000	12000-18000
N	Calibration Factor	0.9 to 1	0.003-0.008	0.003-0.006	0.004-0.007	0.005-0.010
APC-3.5	Calibration Factor	0.9 to 1	-----	0.007-0.009	0.009-0.010	0.010-0.011
N	Effective Efficiency	0.9 to 1	0.003-0.008	0.003-0.005	0.004-0.006	0.005-0.010
APC-3.5	Effective Efficiency	0.9 to 1	-----	0.007-0.008	0.008-0.009	0.009-0.010

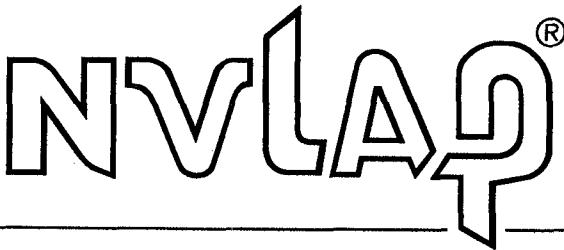
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NVLAP Code: 20/R13
RF/Microwave Attenuators

Reflection Coefficient (or Scattering Parameter S_{ii})

A. HP8510 Vector Network Analyzer Uncertainties

1. Expanded Uncertainties^{notes 1,2,3} on one or two-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-18000	18000-50000
N	S _{ii}	0 to 1	0.001-0.003	0.001-0.009	0.004-0.021	---
APC-7	S _{ii}	0 to 1	0.001-0.007	0.001-0.003	0.001-0.007	---
APC-3.5	S _{ii}	0 to 1	0.001-0.007	0.004-0.020	0.004-0.020	0.004-0.020 (to 26.5 GHz)
2.4 mm	S _{ii}	0 to 1	0.002-0.006	0.001-0.007	0.001-0.010	0.001-0.032
N	Arg(S _{ii})	-180 to +180 deg	0.05-180	0.36-180	1.34-180	---
APC-7	Arg(S _{ii})	-180 to +180 deg	0.15-180	0.16-180	0.33-180	---
APC-3.5	Arg(S _{ii})	-180 to +180 deg	0.53-180	0.33-180	0.33-180	0.33-180 (to 26.5 GHz)
2.4 mm	Arg(S _{ii})	-180 to +180 deg	0.13-180	0.24-180	0.14-180	0.58-180

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2. HP8510 Expanded Uncertainties^{notes 1,2,3} on three-port or four-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-18000	18000-50000
N	$ S_{ii} $	0 to 0.3	0.001 - 0.006	0.001 - 0.006	0.002 - 0.014	---
N	$\text{Arg}(S_{ii})$	-180 to +180 deg	0.13 - 180	0.23 - 180	0.57 - 180	---
N	$ \Gamma_{ge} $	0 to 0.3	0.001 - 0.014	0.002 - 0.019	0.004 - 0.019	---
N	$\text{Arg}(\Gamma_{ge})$	-180 to +180 deg	10 - 180	4.6 - 180	6.3 - 180	---
N	$\text{SR } wc\Delta\rho^{note 10}$	0 to 0.2	0.002 - 0.02	0.002 - 0.05	0.004 - 0.05	---
APC-7	$ S_{ii} $	0 to 0.3	0.001 - 0.005	0.001 - 0.005	0.001 - 0.01	---
APC-7	$\text{Arg}(S_{ii})$	-180 to +180 deg	0.15 - 180	0.16 - 180	0.5 - 180	---
APC-7	$ \Gamma_{ge} $	0 to 0.3	0.001 - 0.005	0.001 - 0.007	0.003 - 0.012	---
APC-7	$\text{Arg}(\Gamma_{ge})$	-180 to +180 deg	3 - 180	3 - 180	3 - 180	---
APC-7	$\text{SR } wc\Delta\rho^{note 10}$	0 to 0.2	0.002 - 0.02	0.002 - 0.05	0.004 - 0.05	---

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APC-3.5	$ S_{ii} $	0 to 0.3	0.002 - 0.007	0.003 - 0.007	0.003 - 0.01	---
APC-3.5	$\text{Arg}(S_{ii})$	-180 to +180 deg	0.6 - 180	0.6 - 180	0.6 - 180	---
APC-3.5	$ \Gamma_{ge} $	0 to 0.3	0.003 - 0.013	0.004 - 0.012	0.004 - 0.12	---
APC-3.5	$\text{Arg}(\Gamma_{ge})$	-180 to +180 deg	3 - 180	3 - 180	3 - 180	---
2.4 mm	$ S_{ii} $	0 to 0.3	---	0.001 - 0.007	0.001 - 0.01	0.003 - 0.02
2.4 mm	$\text{Arg}(S_{ii})$	-180 to +180 deg	---	0.24 - 180	0.14 - 180	0.33 - 180
2.4 mm	$ \Gamma_{ge} $	0 to 0.3	---	0.002 - 0.01	0.003 - 0.12	0.003 - 0.03
2.4 mm	$\text{Arg}(\Gamma_{ge})$	-180 to +180 deg	---	3 - 180	3 - 180	3 - 180

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B. HP8753 Vector Network Analyzer Expanded Uncertainties^{notes 1,2,3}

1. One or two-port devices

Frequency in (MHz)					
Connector Type	Quantity	Quantity Range	0.3 - 25	25-1000	1000-3000
N	$ S_{ii} $	0 to 1	0.001 - 0.013	0.001-0.009	0.003-0.016
APC-7	$ S_{ii} $	0 to 1	0.002 -0.007	0.002-0.04	0.002-0.004
APC-3.5	$ S_{ii} $	0 to 1	0.001 - 0.004	0.006-0.02	0.006-0.035
N	$\text{Arg}(S_{ii})$	-180 to +180 deg	0.06 - 180	0.2-70	1-180
APC-7	$\text{Arg}(S_{ii})$	-180 to +180 deg	0.27 - 180	0.3-180	0.2-180
APC-3.5	$\text{Arg}(S_{ii})$	-180 to +180 deg	0.27 - 180	1-180	1.6-180

2. Three-port or four-port devices^{notes 1,2,3}

Frequency in (MHz)				
Connector Type	Quantity	Quantity Range	0.3 - 25	25 - 3000 (MHz)
N, APC-7-APC-3.5	$ S_{ii} $	0 to 0.3	0.001 - 0.006	0.001 - 0.020
N, APC-7-APC-3.5	$\text{Arg}(S_{ii})$	-180 to +180 deg	0.10 - 180	0.09 - 180
N, APC-7-APC-3.5	$ \Gamma_{ge} $	0 to 0.3	0.003 - 0.005	0.002 - 0.03

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N, APC-7-APC-3.5	Arg(Γ_{ge})	-180 to +180 deg	10 -180	1.9 - 180
N, APC-7	SR wc $\Delta\rho^{note\ 10}$	0 to 0.2	0.001 - 0.006	0.001 - 0.020

Attenuation (or Scattering Parameter S_{ij})

A. HP8510 Vector Network Analyzer Uncertainties

1. Expanded Uncertainties^{notes 1,2,3} on two-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			50-2000	2000-8000	8000-18000	18000-50000
N	$ S_{ij} $	0 to 60 dB	0.01-0.12	0.02-0.17	0.03-0.48	---
APC-7	$ S_{ij} $	0 to 60 dB	0.01-0.08	0.01-0.13	0.01-0.18	---
APC-3.5	$ S_{ij} $	0 to 60 dB	0.01-0.12	0.02-0.22	0.04-0.49	---
2.4 mm	$ S_{ij} $	0 to 60 dB	0.02-0.15	0.02-0.22	0.03-0.34	0.05-2.7
N	Arg(S_{ij})	$0 < S_{ij} < 60$ dB 0 to 360 deg	0.22-1.19	0.32-1.27	0.36-3.46	---
APC-7	Arg(S_{ij})	$0 < S_{ij} < 60$ dB 0 to 360 deg	0.22-0.73	0.25-1.21	0.41-2.85	---
APC-3.5	Arg(S_{ij})	$0 < S_{ij} < 60$ dB 0 to 360 deg	0.45-0.80	0.35-1.39	0.41-3.17	---

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2.4 mm	Arg(S_{ij})	$0 < S_{ij} < 60$ dB 0 to 360 deg	---	1.1-1.7	1.1-1.7	1.3 - 21.0
--------	-----------------	--	-----	---------	---------	------------

2. HP8510 Expanded Uncertainties^{notes 1,2,3} on three-port or four-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)		
			50-2000	2000-8000	8000-18000
N, APC-7, APC-3.5	Mainline/ Coupling $ S_{ij} $	0 to 40 dB	0.01 - 0.12	0.02 - 0.12	0.01 - 0.43
N, APC-7, APC-3.5	Isolation $ S_{ij} $	40 to 80 dB	0.2 - 16	0.4 - 9	0.9 - 17
2.4 mm	Mainline/ Coupling $ S_{ij} $	0 to 40 dB	---	0.03 - 0.15	0.04 - 0.5
2.4 mm	Isolation $ S_{ij} $	40 to 85 dB	---	0.4 - 10	1.0 - 12
					1.5 - 15

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B. HP8753 Vector Network Analyzer Expanded Uncertainties^{notes 1,2,3}

1. Two-port devices

Connector Type	Quantity	Quantity Range	Frequency (MHz)		
			0.3 - 25	25 - 1000	1000-3000
N	$ S_{ij} $	0 to 60 dB	0.02-0.25	0.003-0.5	0.004-1.2
APC-7	$ S_{ij} $	0 to 60 dB	0.01-0.16	0.002-0.6	0.003-0.9
APC-3.5	$ S_{ij} $	0 to 60 dB	0.01-0.22	0.003-0.6	0.003-1.0
N, APC-7, APC-3.5	$\text{Arg}(S_{ij})$	-180 -to +180 deg	1.4-13	0.4-10	0.4-10

2. Three-port or four-port devices

Connector Type	Quantity	Quantity Range	0.3-25	25-3000 (MHz)
N, APC-7-APC-3.5	Mainline/Coupling $ S_{ij} $	0 -40 dB	0.008 -0.2	0.020 - 0.3
N, APC-7-APC-3.5	Isolation $ S_{ij} $	40 to 87 dB	0.1 -13.6	0.1 - 13.8

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C. Power Ratio Attenuation Expanded Uncertainties^{notes 1,2,3}

Connector Type	Quantity	Quantity Range	Frequency (MHz)			
			10-2000	2000-8000	8000-12000	12000-18000
Fixed Attenuators						
N, APC-7 APC-3.5	S _{ij}	0 to 11 dB	0.007-0.014	0.008-0.021	0.010-0.025	0.016-0.026
Isolated Step/Variable Attenuators						
N, APC-7 APC-3.5	S _{ij}	0 to 11 dB	0.007-0.014	0.007-0.016	0.007-0.015	0.007-0.018

NVLAP Code: 20/R16

Group Delay Expanded Uncertainties^{notes 1,2,3,4}

Connector Type	Typical Atten. (dB)	Delay (ns)	50-1000	1000 - 50000
APC-7, N, APC-3.5, 2.4 mm	0 - 10	5 - 500	0.02 - 0.5	0.02 - 1.0

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RF/Microwave Power Meters

Power Meter Certification Uncertainties^{notes 2,3,4,11}

A. Low to Medium Power CW Microwave Power Meters at Type N Connector

Frequency (MHz)

k=3 uncertainties

<i>Quantity</i>	<i>Quantity Range</i>	<i>10 to 2000</i>	<i>2000 to 4000</i>	<i>4000 to 12400</i>	<i>12400 to 18000</i>
Power (dBm)	-30 to -10	.09 to .41 dB	.13 to .41 dB	.14 to .34 dB	.16 to .46 dB
Power (dBm)	-10 to 10	.06 to .27 dB	.10 to .25 dB	.11 to .30 dB	-----
Power (dBm)	10 to 30	.06 to .25 dB	.10 to .21 dB	.11 to .24 dB	-----

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B. Low Power, Wide Range, CW Microwave Power Meters at Type N Connector

Frequency (MHz)

k=3 uncertainties

<i>Quantity</i>	<i>Quantity Range</i>	<i>10 to 4000</i>	<i>4000 to 8000</i>	<i>8000 to 18000</i>
Power (dBm)	-60 to -50	0.20 to 0.48 dB	0.24 to 0.43 dB	0.24 to 0.43 dB
Power (dBm)	-50 to -40	0.17 to 0.33 dB	0.20 to 0.35 dB	0.20 to 0.42 dB
Power (dBm)	-40 to -30	0.14 to 0.27 dB	0.16 to 0.32 dB	0.20 to 0.36 dB
Power (dBm)	-30 to -20	0.14 to 0.26 dB	0.14 to 0.27 dB	0.18 to 0.35 dB

C. Medium Power CW Microwave Power Meters at Type N Connector

Frequency (MHz)

k=3 uncertainties

<i>Quantity</i>	<i>Quantity Range</i>	<i>10 to 2000</i>	<i>2000 to 2500</i>
Power (mW)	1 to 10	1.76 to 3.30%	-----
Power (mW)	1 to 160	-----	1.95 to 4.29%

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D. Medium Power CW Microwave Power Meters at APC-3.5 Connector

Frequency (MHz)

k=3 uncertainties

<i>Quantity</i>	<i>Quantity Range</i>	<i>2000 to 4000</i>	<i>4000 to 8000</i>	<i>8000 to 18000</i>
Power (mW)	0.1 to 8	2.81 to 4.02%	2.99 to 4.92%	3.97 to 5.83%

E. High Power CW Microwave Power Meters at Type N Connector

Frequency (MHz)

k=3 uncertainties

<i>Quantity</i>	<i>Quantity Range</i>	<i>10 to 300</i>	<i>300 to 3000</i>
Power (Watts)	0.2 to 10	8.97 to 9.1%	3.26 to 10.61%
Power (Watts)	10 to 200	4.36 to 10.13%	9.60 to 10.60%

F. Pulse Power Meters at Type N Connector

k=3 uncertainties

<i>Quantity</i>	<i>Quantity Range</i>	<i>Pulse Width Range</i>	<i>PRF Range</i>	<i>2000 to 18000</i>
Power (mW)	10 to 100	0.2 μ s to 5 μ s	1 to 20 kHz	7.32 to 8.16%

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THERMODYNAMICS

NVLAP Code: 20/T04

Leak Artifacts

Range	Best Uncertainty (\pm) in percent ^{note 1}	Remarks
Gas Leak - PΔV Technique		
1×10^{-7} moles/s	0.7	Total Gas Measurement
1×10^{-8} moles/s	0.9	Total Gas Measurement
1×10^{-9} moles/s	1.0	Total Gas Measurement
1×10^{-10} moles/s	1.0	Total Gas Measurement
Gas Leak - Accumulate - Dump Technique		
1×10^{-10} moles/s to 1×10^{-14} moles/s	1.0	1 to 200 Atomic Mass Units for any non- reactive, non-hazardous, non-radioactive gas
Gas Leak - Comparison Technique		
1×10^{-10} moles/s	2.5	Helium
1×10^{-11} moles/s	2.4	Helium
1×10^{-12} moles/s	2.3	Helium
1×10^{-13} moles/s	2.3	Helium

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1×10^{-14} moles/s

7.0

Helium

NVLAP Code: 20/T05

Pressure

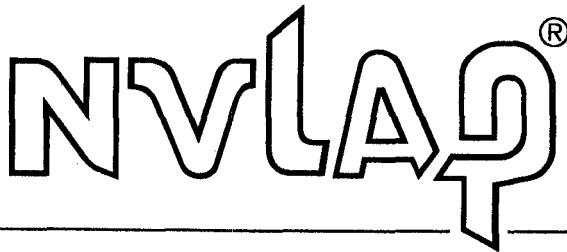
Range	Best Uncertainty (\pm) in ppm ^{note 1}	Remarks
Pneumatic Deadweight Piston Gauges (absolute mode) - Direct Pressure Comparison		
0.2 to 24 psia [\approx 1.4 to 170 kPa]	31	Nitrogen
2.0 to 70 psia [\approx 14 to 480 kPa]	28	Nitrogen
52 to 1000 psia [\approx 0.4 to 7.0 MPa]	46	Nitrogen
Pneumatic Deadweight Piston Gauges (gauge mode) - Direct Pressure Comparison		
0.2 to 24 psig [\approx 1.4 to 170 kPa]	29	Nitrogen
2.0 to 70 psig [\approx 14 to 480 kPa]	26	Nitrogen
52 to 1000 psig [\approx 0.4 to 7.0 MPa]	44	Nitrogen
Hydraulic Deadweight Piston Gauges (gauge mode) - Direct Pressure Comparison		
0.4 to 4.0 kpsig [\approx 2.8 to 28 MPa]	44	Oil
2.0 to 20 kpsig [\approx 14 to 140 MPa]	61	Oil
4.0 to 40 kpsig [\approx 28 to 280 MPa]	59	Oil

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Pneumatic Deadweight Piston Gauges - Cross Float (effective area)

0.2 to 24 psig [\approx 14 kPa to 170 kPa]	35	Nitrogen
2.0 to 70 psig [\approx 14 kPa to 480 kPa]	33	Nitrogen
52 to 1000 psig [\approx 0.4 MPa to 7.0 MPa]	46	Nitrogen

Hydraulic Deadweight Piston Gauges - Cross Float (effective area)

0.4 to 4.0 kpsig [\approx 2.8 to 28 MPa]	46	Oil
2.0 to 20 kpsig [\approx 14 to 140 MPa]	67	Oil
4.0 to 40 kpsig [\approx 28 to 280 MPa]	61	Oil

Secondary Pressure

Low Range Absolute

Pressure	Best Uncertainty (\pm) in psia ^{note 1}	Remarks
0.2 psia [\approx 1.4 kPa]	0.0013	Nitrogen
1.0 psia [\approx 7.0 kPa]	0.0013	Nitrogen
6.0 psia [\approx 41 kPa]	0.0017	Nitrogen
10 psia [\approx 70 kPa]	0.0021	Nitrogen
15 psia [\approx 100 kPa]	0.0028	Nitrogen

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Secondary Pressure
Low Range Gauge or Absolute

Pressure	Best Uncertainty (\pm) in psi ^{note 1}	Remarks
20 psi [≈ 140 kPa]	0.009	Nitrogen
40 psi [≈ 280 kPa]	0.010	Nitrogen
60 psi [≈ 410 kPa]	0.011	Nitrogen
80 psi [≈ 550 kPa]	0.013	Nitrogen
100 psi [≈ 690 kPa]	0.014	Nitrogen

Secondary Pressure
Mid-Range Gauge or Absolute

Pressure	Best Uncertainty (\pm) in psi ^{note 1}	Remarks
200 psi [≈ 1.4 MPa]	0.137	Nitrogen
500 psi [≈ 3.4 MPa]	0.157	Nitrogen
1.0 kpsi [≈ 7.0 MPa]	0.201	Nitrogen
1.5 kpsi [≈ 10 MPa]	0.247	Nitrogen
2.0 kpsi [≈ 14 MPa]	0.280	Nitrogen

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Secondary Pressure
High-Range Gauge or Absolute

4.0 Kpsi [\approx 28 MPa]	0.6	Nitrogen
6.0 Kpsi [\approx 41 MPa]	0.8	Nitrogen
8.0 Kpsi [\approx 55 MPa]	1.0	Nitrogen
10 Kpsi [\approx 70 MPa]	1.0	Nitrogen

NVLAP Code: 20/T07
Resistance Thermometry

Temperature ($^{\circ}$ C)	Best Uncertainty (\pm) in m $^{\circ}$ C ^{note 1}	Material/ Equilibrium State
-189.3442	0.53	Ar/Triple Point
-38.8344	0.30	Hg/Triple Point
0.01	0.16	H ₂ O/Triple Point
29.7646	0.12	Ga/Melting Point
156.5985	2.00	In/Freezing Point
231.928	0.92	Sn/Freezing Point
419.527	1.10	Zn/Freezing Point
660.323	5.0	Al/Freezing Point

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961.78	10.0	Ag/Freezing Point
Standard Platinum Resistance Thermometer Calibrations		
-189.3442	1.1	Ar/Triple Point
-38.8344	0.6	Hg/Triple Point
0.01	0.6	H ₂ O/Triple Point
29.7646	0.6	Ga/Melting Point
156.5985	2.6	In/Freezing Point
231.928	1.8	Sn/Freezing Point
419.527	2.0	Zn/Freezing Point
660.323	5.2	Al/Freezing Point
961.78	10.1	Ag/Freezing Point

Comparison Calibrations

Temperature Range (°C)	Best Uncertainty (\pm) in °C ^{note 1}	Type of Device
-80 to 0	0.10	Thermocouples
10 to 150	0.10	Thermocouples
150 to 660	0.22	Thermocouples

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660 to 700	0.47	Thermocouples
700 to 1100	2.5	Thermocouples
1100 to 1300	2.8	Thermocouples
-80 to 0	0.06	RTD/IPRT/PRT
10 to 150	0.09	RTD/IPRT/PRT
150 to 660	0.21	RTD/IPRT/PRT
-80 to 0	0.05	Liquid in Glass
10 to 150	0.06	Liquid in Glass
-80 to 0	0.06	Thermistors
10 to 150	0.09	Thermistors
150 to 250	0.21	Thermistors

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Thermocouple Simulator/Readout Calibration Methods

Type	ITS-90 Temperature Range (°C)	Best Uncertainty (\pm) in °C ^{notes 1,8}	NIST Monograph 175 Reference Table ^{note 9}
K	-200 TO 1370	0.10 to 0.30	7.3.3
J	-200 to 1200	0.08 to 0.22	6.3.3
E	-240 to 1000	0.07 to 0.38	5.3.3
T	-240 to 400	0.09 to 0.53	9.3.3
R	-50 to 1750	0.38 to 1.09	3.3.3
S	-50 to 1750	0.43 to 1.02	4.3.3
B	100 to 1750	0.43 to 4.45	2.3.3
C	0 to 2300	0.24 to 0.82	

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NVLAP Code: 20/T10

Vacuum

<i>Range</i>	<i>Best Uncertainty (\pm) in percent^{note 1}</i>	<i>Remarks</i>
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Ionization Gage Reference for direct comparison

$1.3 \times 10^{-6} \text{ Pa} < \text{reading} \leq 1.3 \times 10^{-5} \text{ Pa}$	4.8	$\text{N}_2; 10^{-8} \text{ Torr}$
$1.3 \times 10^{-5} \text{ Pa} < \text{reading} \leq 1.3 \times 10^{-4} \text{ Pa}$	4.7	$\text{N}_2; 10^{-7} \text{ Torr}$
$1.3 \times 10^{-4} \text{ Pa} < \text{reading} \leq 1.3 \times 10^{-3} \text{ Pa}$	4.7 - 2.5	$\text{N}_2; 10^{-6} \text{ Torr}$

Spinning Rotor Gage Reference for direct comparison

$1.3 \times 10^{-4} \text{ Pa} < \text{reading} \leq 1.3 \times 10^{-3} \text{ Pa}$	4.3 - 2.1	$\text{N}_2; 10^{-6} \text{ Torr}$
$1.3 \times 10^{-3} \text{ Pa} < \text{reading} \leq 1.3 \text{ Pa}$	2.1	$\text{N}_2; 10^{-5} \text{ Torr} - 10^{-3} \text{ Torr}$
$1.3 \text{ Pa} \leq \text{reading} \leq 13 \text{ Pa}$	2.2	$\text{N}_2; 10^{-3} \text{ Torr}$

Capacitance Diaphragm Gage Reference for Direct Comparison

$1.3 \times 10^{-1} \text{ Pa} \leq \text{reading} \leq 13.3 \text{ Pa}$	2.1 - 0.7%	$\text{N}_2; 0.1 \text{ Torr}$
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Forced Balance and Deadweight Piston Gauges - Direct Pressure Comparison (Absolute, Absolute Differential and Gauges Modes)

0.3 Pa to < 6.0 Pa	30 ppm + 0.025 Pa	N ₂ ; 0.1 Torr range
>6.0 Pa to 15.0 kPa	30 ppm + 0.008 Pa	N ₂ ; 0.1, 1, 10, 100 Torr range
15.0 kPa to 133.3 kPa	31 ppm	N ₂ ; 1000 Torr range

Secondary Capacitance Diaphragm Gages Reference for direct comparison (Note: uncertainty in % of reading)

1.3 x 10 ⁻¹ Pa ≤ reading ≤ 13.3 Pa	2.3 to 0.5	N ₂ ; 0.1 Torr range
13.3 Pa ≤ reading ≤ 133.3 Pa	0.6	N ₂ ; 1 Torr range
133.3 Pa ≤ reading ≤ 1.3 kPa	0.4	N ₂ ; 10 Torr range
1.3 kPa ≤ reading ≤ 13.3 kPa	0.3	N ₂ ; 100 Torr range
13.3 kPa ≤ reading ≤ 133.3 kPa	0.3 to 0.05	N ₂ ; 1000 Torr range

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1. Expanded uncertainty with coverage factor of $k=2$, unless otherwise specified.
2. Approximate value. Actual value determined by test results.
3. The uncertainty ranges are the lowest and highest uncertainty values within the specified frequency range and quantity range.
4. Certification uncertainty consists of an appropriate combination of the measurement uncertainty (which includes all significant sources of uncertainty associated with the calibration process) and uncertainties due to use, environment, handling or variation with time over the certification interval.
5. ASTM loading range classes (e.g., A, AA) are not used or reported.
6. Calibrations to 30,000 lbf versus load cells can be automated; other calibrations are manual.
7. Uncertainties listed are linearized forms ($A' + B'L$) of uncertainties calculated as root sum squares of constant and length-dependent terms $\{A^2 + (BL)^2\}^{1/2}$. A' and B' are calculated by fitting a straight line through the RSS uncertainty values at the upper and lower limits of range.
8. Uncertainty is dependent on the specific temperature point tested.
9. Referenced tables in NIST Monograph 175 (April, 1993) provide values for emf E output/input of the thermocouple simulator/readout and the Seebeck coefficient S for the specific temperature points within the specified ranges. The best uncertainty (at $k=2$) of the emf E in μV is equal to the product of $U * S$, where U is the best uncertainty (at $k=2$) of the temperature point tested.
10. SR wc $\Delta\rho$ is the worst-case error in measurement of reflection coefficient, ρ , ($0.5 \geq \rho \geq 0$) as made by a 4-port scalar reflectometer which has rf access to all 4 ports. Uncertainty shown in the table is the uncertainty on value of SR wc $\Delta\rho$.
11. User mismatch uncertainty not included.

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